

A STUDY OF MISBEHAVIOR: TOKEN REINFORCEMENT IN THE RAT¹

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The purpose of this research was to investigate the phenomenon of misbehavior described by Breland and Breland (1961). Rats were trained to obtain ball-bearings and drop them in a hole for food or water reinforcers. In confirmation of the Brelands' observation, many subjects were slow to deliver the balls, and frequently attempted to chew them before they were dropped. A series of four experiments, in which the same rats were used throughout, showed that delivery times tended to be longer with food than with water, and that these times increased when nylon balls were substituted. The effect of motivational level was investigated by varying both deprivation and amount of prefeeding; no effect on delivery time was detected, although other measures of performance were affected by motivational factors. Similar results were obtained in a final experiment that employed a new set of naive subjects. The studies demonstrated that misbehavior can be studied in an experimental situation, and the results supported an analysis in terms of competition between stimulus-reinforcer and response-reinforcer contingencies. The question of why such effects have not been reported in previous token reinforcer studies was unanswered.

Key words: misbehavior, token reinforcement, food and water reinforcement, motivational factors, chain schedules, rats

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The term *misbehavior* was coined by Breland and Breland (1961) and applied by them

to a variety of puzzling behaviors that appeared to provide exceptions to the law of effect. In general, they were very successful in their use of instrumental conditioning methods, with animals rarely found in a laboratory, to obtain behavior sequences far more complex than those typically studied in an experimental context (Breland and Breland, 1951). However in certain situations, they observed what they described as a "drift" from conditioned to instinctive behavior: a response specific to the species of animal would appear in place of the arbitrary response required by the training schedule. In many cases, this apparently competing response resembled patterns of food-seeking behavior observed in more natural settings. The term "misbehavior" was used for such responding where it appeared to prevent, delay, or reduce the amount of reinforcement available when the instrumental response was completed.

The Brelands' most striking examples of the phenomenon occurred in situations involving token reinforcers. For example, when raccoons were trained to collect a wooden disc and deposit it in a box in order to obtain food, the raccoons became progressively slower in depositing tokens, and correspondingly spent an in-

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creasing amount of time rubbing and kneading them, behavior normally displayed by such animals toward food objects (Breland and Breland, 1961). Similar observations were made with other species, although the way they behaved towards the token varied with the species (Breland and Breland, 1966, pp. 67-68).

Research in autoshaping has discovered phenomena that appear to be closely related to many of the Brelands' examples. This is illustrated by studies of pigeons in a "long box" (Hearst and Jenkins, 1974), where the occasional presentation of response-independent grain is preceded by the brief illumination of a response key 0.6 to 0.9 m from the grain hopper. A commonly observed pattern of behavior is for a pigeon to approach and peck the lit key and then, when grain arrives, rush to the hopper. If the grain is available only for a short time, approaching the lit key may reduce the amount of grain that the pigeon obtains, since it may return from the key only shortly before the grain is withdrawn. For example, in an unpublished study using a long box, we found that with the signal present, some pigeons would obtain less than half the amount of grain they obtained without the signal. This kind of maladaptive behavior by pigeons in an autoshaping situation resembles many of the examples of misbehavior described by the Brelands, in that the development of a pattern of behavior, which is not specified by any explicit response contingency, is accompanied by a decrease in the rate with which the animal obtains the reinforcer. Much of the behavior of pigeons in an autoshaping situation can be understood as resulting from the interaction of classical and instrumental conditioning, and it has been suggested (*i.e.*, Jenkins and Moore, 1973; Moore, 1971) that many of the Brelands' instances of misbehavior can be explained in the same way.

To explore this possibility, the present study sought to extend the rather fragmentary reports by the Brelands and attempted to reproduce the phenomenon in a laboratory setting. There were two further aims to the research. One was to investigate the effects of varying the type of primary reinforcer used. In an autoshaping situation, behavior toward the conditioned stimulus can be affected by the type of unconditioned stimulus employed (Hearst and Jenkins, 1974). The Brelands' account also suggests that their raccoons would not have treated

the tokens as effective food objects if water had been the reinforcer for depositing the tokens in the box.

A final aim was to determine the effects of motivational variables. When training a pig to deposit tokens and finding that its behavior began to deteriorate, the Brelands attempted to counteract this "drift" by increasing the animal's level of food deprivation; they found that the pig became even slower to relinquish the token (Breland and Breland, 1961, pp. 683-684). While such further deterioration may have happened anyway, this observation does raise the intriguing possibility that misbehavior becomes stronger with increased deprivation.

EXPERIMENT I: INITIAL TRAINING AND EFFECTS OF VARYING DEPRIVATION

METHOD

Subjects

Twenty male hooded rats with varied experimental histories were given at least part of the training described below. Their prior experience did not include any instrumental conditioning involving either food or water reinforcement. From the outset, seven were maintained on a 23.5-hr water-deprivation schedule, whereby they were given a half hour free access to water after each session.

Following the training phase, only six subjects from each group were used, and their deprivation conditions are described below.

Apparatus

The chamber used is illustrated in Figure 1. Steel ball-bearings of 8 mm diameter could be delivered into a tray in the recess behind the ball-flap, 45-mg food pellets (Camden Instruments Ltd.) delivered into a tray behind the pellet flap, and a 0.1-cc water dipper could be presented behind the water flap. Each of these three recesses could be illuminated by a 1-W 24-V dc bulb. All three flaps were made of clear Plexiglas, were hinged along the top, and mounted in such a way that a small displacement operated a microswitch. Two 1-W 24-V dc bulbs mounted centrally high on the side walls served as houselights.

When a ball-bearing was deposited in the hole, it rolled a short distance along a channel

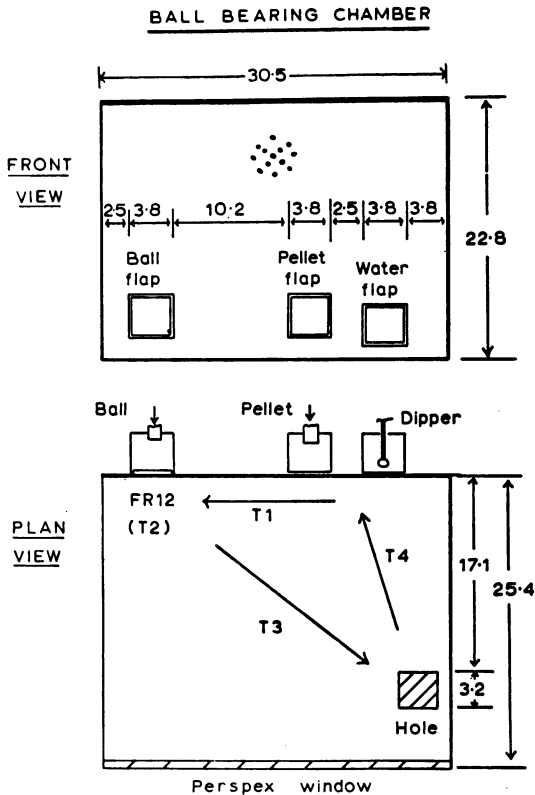


Fig. 1. Dimensions of experimental chamber in centimeters. T1, T2, T3, and T4 indicate the parts of the behavior sequence timed in Experiment I. In the subsequent experiments, production of the ball was on a VI schedule, instead of the FR 12 indicated here, and response rates replaced the T2 measure.

beneath the floor and triggered a photocell. A white masking noise was present throughout each session. Experimental conditions were controlled by conventional electromechanical equipment.

Procedure

The experiment was carried out in two phases: a training phase, under the constant deprivation conditions described above, and a performance phase, under varied conditions of reinforcement.

The task required the subjects to push 12 times on the ball flap, whereupon a ball was delivered; then to carry the ball to the hole and drop it in. For the food-deprived rats, depositing the ball was always immediately followed by the delivery of a food pellet and for the water-deprived rats by the operation of the water dipper. Reinforcement was ac-

companied by illumination of the appropriate recess and flap, cessation of the white noise, and flashing of the houselights. Subsequent operation of the appropriate flap switched off the flap light and switched on the noise and houselights, thus setting up conditions for the next trial. Each training session ended when approximately 80 reinforcements had been delivered.

The method of successive approximations was used to shape each component in this chain of behavior, starting with the final component and working backward. Initially, following appropriate magazine training, a number of balls were placed close to the hole and touching the balls with the paw was reinforced. Then picking up and dropping, or scooping, the balls into, or near to, the hole was shaped. At the end of this first stage, subjects would take a ball that had been placed within about 2.5 cm of the hole and drop it in. In the next stage, the balls were moved further from the hole and nearer to the ball flap, until the animal was retrieving the ball from the recess. At this point, delivery of the ball was made dependent on a single ball-flap response; in the final stage, the number of responses required was progressively increased to a fixed ratio of 12.

The six subjects from each group that reached the end of training were given from three to five further sessions, each containing 27 trials under the terminal conditions. They were then kept in their home cages with unlimited access to food and water for a period of one to three weeks. After estimates of their free-feeding weights were obtained from the median weight over the final five days of this period, rats in the food group were again deprived of food and rats in the water group put on a schedule of 20-min access to water daily, as described below.

Each of these remaining subjects was given three blocks of five sessions with different deprivation levels for each block. Food-reinforced rats were deprived of food until they were either 75%, 82.5%, or 90% of their free-feeding weights. Water-reinforced rats were given 20-min access to water daily, either 4, 16, or 24 hr before the experimental session. Within both groups, each subject was given a different sequence of deprivation conditions, so that all of the six possible sequences were employed. There were two intervening days between each

block to allow adjustment to the next deprivation schedule.

Experimental conditions remained constant during the 15 sessions and were exactly as during the final phase of the training procedure. Each session contained 27 trials. On all but the first trial, times to complete the different parts of the sequence were obtained to the nearest 0.25 sec.

Throughout the final two sessions of each block, each subject was watched by an observer (one of the first three authors RAB, MP, or MJL) who recorded the duration of various categories of behavior during the ball-delivery period, T3, using a push-button arrangement. Four categories were decided on the basis of informal observations during the last stage of shaping. These categories were: (a) "mouth contact", where the rat's mouth was in physical contact with the ball; (b) "stationary", where the animal did not move, but maintained contact with the ball; (3) "lost ball", where the rat was no longer in contact with the ball; and (d) "ball in the hole", where the ball had been placed in the hole, but not yet released by the animal. This last category occurred infrequently once systematic observation was begun and will receive no further mention. In addition, a brief description of each subject's behavior was recorded immediately after these sessions and without any reference to previous descriptions. These records for each rat were made by at least two of the experimenters.

RESULTS

Of the seven food rats, one was rejected when after a considerable time we had still failed to train it to pick up the balls. Of the six that served as experimental subjects, five required between 10 and 20 sessions of training and one only seven sessions to reach the terminal stage. With most of these subjects, the most difficult parts of the training procedure was depositing the ball in the hole and, once this had been achieved, the transition from retrieving balls close to the hole to retrieving balls placed a centimeter or so further away.

Of the 13 water rats, one died after completing training and a further six were rejected, most because shaping was unsuccessful at an early stage of training. Of the six that served, four required between 10 and 20 training sessions, one six sessions, and one only five.

As suggested by the rejection figures, water rats appeared to be harder to train, particularly in the early stages. However, hand-shaping methods are inherently variable, the subjects in the two groups were not matched, and motivational levels were probably not comparable. Consequently, no conclusion can be drawn on this point.

Late in training, many of the rats began to display behavior resembling that described by the Brelands: having obtained a ball, some became slow in depositing it in the hole. A considerable part of the ball-delivery period was spent in putting the ball in their mouths.² Observation during the experimental procedure revealed three distinct behavior patterns. Subjects were found to show the same pattern in each observation session.

The fastest ball-delivery (T3) times were obtained from rats showing Pattern A: the ball was seized in the mouth and quickly carried in the mouth, or between paws and mouth, either directly to the hole, when it was immediately dropped in, or to within a centimeter or so of the hole, whereupon it was placed on the floor and nosed into the hole. Three water rats showed this pattern, and their average T3 times were: R3, 6.5 sec; R6, 3.5 sec; and R22, 5.5 sec. With the most common pattern, Pattern B, the ball was carried in the mouth to within a centimeter of the hole, either directly or with occasional stops en route to mouth the ball. A rat would then sit by the hole, repeatedly alternating between putting the ball to its mouth and turning it in its paws, before eventually dropping it in the hole. Occasionally, some rats showing this pattern would rapidly retrieve the ball from the hole before it rolled out of reach. A further two rats, R10 and R11, had a curious style of delivering the ball. With the ball between their forepaws, they would extend their heads forward to the far side of the hole before dropping the ball; anthropomorphically, it was as if this maneuver allowed them to avoid seeing the ball disappear. Subjects showing Pattern B could be divided into two sub-groups. With three food subjects, the period spent within a centimeter of the hole was relatively long, of the order of at least 12

²A 16-mm black and white film illustrating behavior in this situation is obtainable from the Laboratory of Experimental Psychology, University of Sussex.

to 15 sec, and their average T3 times were: R10, 22 sec; R16, 20 sec, and R19, 17 sec. With four remaining subjects, the time spent by the hole was somewhat shorter. These included three water subjects, whose average times were R11, 14.5 sec; R12, 12 sec, and R13, 14 sec, and one food subject, R18 with a T3 time of 8 sec. The final pattern, Pattern C, was shown by two food subjects, which gave the longest T3 times: R17, 27 sec and R20, 29 sec. After seizing the ball they would stay within a centimeter of the ball flap for a number of seconds, while they mouthed the ball in the way described for Pattern B. They would then turn and start toward the hole, stopping once or twice en route to mouth the ball. Once at the hole, the ball was deposited rapidly.

Timing by the observers during the two final sessions of each block indicated that a high percentage of the T3 times of all subjects was spent with the ball in contact with the mouth. There was no difference between the groups and no within-subject effect of deprivation level on this measure. Taking the median for each subject over the three deprivation conditions, the range for the six food subjects was 70 to 85%, and for the water subjects 61 to 82% of the total T3 time.³ Correspondingly, only a small contribution to total T3 times was made by periods in which the rat lost contact with the ball, and again there was no difference between the groups. However, in this case, a reliable effect of deprivation was observed in the food group (Friedman, $\chi^2 = 10.3$, $p < 0.01$): all subjects gave the longest "lost-ball" times in the 75% condition and, with one exception, the shortest times in the 90% condition. A similar trend for lost-ball times to increase with increased deprivation was also shown, though less consistently, by the water group. Most lost-ball time occurred

when a rat missed the hole, and the above effect thus appeared to be one of decreased accuracy in placing the ball as motivation increased. This time made little contribution to the total T3, ranging for the food rats from an average of 0.6% at the lowest deprivation level to 3% at the highest level.

The results considered so far have been those recorded by the observers. In addition, times to complete four parts of the sequence were recorded automatically. As shown in Figure 1, these were: T1, the initial latency to the first ball-flap response measured from the operation of the appropriate reinforcer flap following delivery of the reinforcer on the previous trial; T2, the time to complete the remaining 11 responses on the ball-flap; T3, ball delivery time from the release of the ball into the recess behind the ball-flap until its delivery into the hole triggered the photo-cell; and T4, the time from ball delivery to the operation of the appropriate reinforcer flap. The datum of most interest, T3, was recorded on each trial, while the other times were cumulated over the session. Mean T1, T2, and T3 times for the final three sessions of each block are shown in Figure 2 for the different deprivation conditions.

Within-subject comparisons were tested using Friedman's two-way analysis of variance. No effect of deprivation on the duration of the ball-delivery period (T3) was detected in either group ($p > 0.25$ in both tests). Other measures of performance were found to vary as a function of deprivation level. Initial latencies to the first ball-flap response decreased reliability with increasing deprivation in the water group ($\chi^2 = 7.0$; d.f. = 2; $p = 0.03$), though a similar decrease in the food group just failed to reach significance ($\chi^2 = 5.3$; $p = 0.07$). Time to collect the reinforcer (T4) was reliably reduced by increasing deprivation in the food group ($\chi^2 = 8.3$; $p = 0.01$), even though these times and the differences were small. No effect of deprivation on T2 times was detected in either group ($p > 0.25$).

Between-group comparisons were based on the median times for each subject under the three deprivation levels. The individual T3 times given above were obtained in this manner. In the food group, T1 times were reliably shorter (Mann-Whitney $U = 32$, two-tailed, $p < 0.05$) and T3 times longer ($U = 33$, two-tailed, $p < 0.025$) than in the water group.

³Since, under the conditions of the experiment, the simultaneous presence of two independent observers was not possible, no direct estimate of interobserver reliability was available. However, an indirect estimate was gained by comparing the percentage of T3 time when the ball was in contact with an animal's mouth during the last session of a given deprivation condition, as recorded by one observer, with the percentage recorded on the previous session by a different observer. Over the 36 pairs of recordings, the mean discrepancy was 8.8% (s.d. 6.2). This provides a conservative estimate of the degree of agreement between observers, since between-session variability may have made a major contribution to the observed discrepancies.

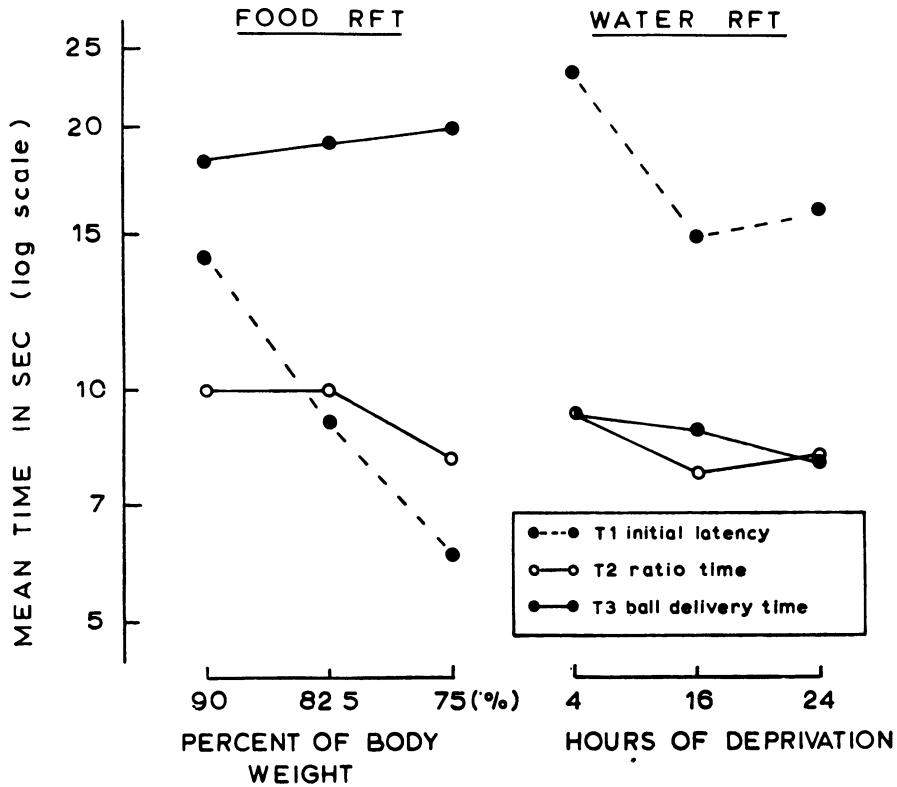


Fig. 2. Experiment I: time to complete portions of the sequence as a function of deprivation condition. The T1 and T3 measures shown here are geometric means of the data presented in Table I.

No differences between the groups were detected in terms of T2 or T4 times.

The data obtained from individual subjects are given in Table 1.

Trial-by-trial data on T3 times were examined for possible sequential effects and for changes in their distribution. Performance was found to be stable within a session in the food group, whereas a slight trend for T3 to increase as a session progressed was detected

in the water group. This was analyzed by dividing the final two sessions of each condition into four successive blocks of six trials, starting with Trial 3, and obtaining the average T3 times within a block. The trend was most pronounced in the 4-hr deprivation condition, where an average increase of 35% between the first and the last block was obtained. However, even in this condition the trend was not reliable ($p > 0.05$), and overall this analysis in-

Table 1

Experiment I: initial latencies (T1 in seconds) and ball-delivery times (T3 in seconds) for each subject. The first number indicates T1 and the second (in parenthesis) T3. Medians for the final three sessions of each deprivation condition are shown.

Subjects	Food Reinforcer Per cent of Bodyweight			Subjects	Water Reinforcer Hours of Deprivation		
	90	82.5	75		4	16	24
R10	36.8 (20.2)	7.6 (22.0)	6.2 (23.4)	R3	50.9 (5.8)	33.6 (6.5)	50.4 (6.8)
R16	11.8 (21.2)	14.5 (16.7)	8.1 (20.2)	R6	21.0 (3.6)	15.8 (4.5)	15.5 (3.6)
R17	16.9 (20.6)	8.7 (30.6)	5.0 (27.0)	R11	50.9 (24.2)	18.4 (14.5)	15.7 (13.0)
R18	6.0 (7.7)	5.0 (7.2)	6.1 (10.2)	R12	26.8 (12.3)	15.1 (12.0)	14.2 (10.6)
R19	4.3 (19.6)	6.6 (16.8)	9.2 (16.8)	R13	16.5 (13.9)	9.5 (13.2)	13.8 (14.8)
R20	8.0 (29.0)	14.6 (37.0)	17.5 (29.1)	R22	7.6 (5.7)	7.7 (5.6)	7.1 (5.4)

licated that the main results would have been little affected by the use of longer sessions. Distributions of T3 times were unimodal and no effect of deprivation level on the form of these distributions or on the median was detected.

The main results of this experiment may be summarized as follows. A large number of subjects showed patterns of behavior, B and C, that involved considerable delays in delivering the ball. Such patterns were shown by all six of the food rats. Three of the water rats showed Pattern A, which involved no delay, and overall the delivery times of the water group were reliably shorter—on average they took about half the time—than those of the food rats. Nonetheless, three rats in the water group showed behavior that was qualitatively indistinguishable to the observers from that shown by four rats in the food group. Increasing deprivation in the food group decreased, though not very reliably, the initial latency (T1) and produce small, but reliable, decreases in the time to collect a pellet (T4) and increases in “lost-ball” time. Increasing deprivation in the water group reliably decreased initial latencies. For many subjects, the longest segment of a trial was the ball-delivery period (T3); yet, despite this and despite the effects of deprivation noted above, T3 times remained constant over the range of conditions investigated. Although this result was not the one anticipated on the basis of the Brelands’ experience with their pig, it does at least strongly suggest that the difference between the groups in terms of T3 times did not arise because of different levels of motivation.

EXPERIMENT II: FURTHER TRAINING AND USE OF A PREFEEDING PROCEDURE

In Experiment I, the groups differed in two respects: in the type of reinforcer they received and in the state of deprivation in which they were maintained. Either of these confounded factors may have been responsible for the greater amount of misbehavior, as measured in terms of longer T3 times, observed in the food group. There were two principal aims to this second experiment. One was to compare food and water reward, when deprivation conditions were the same in both

groups. The second was to examine further the effects of motivational factors on performance. The failure to detect any change of T3 times following changes in deprivation might have occurred because of variability inherent in the testing procedure, whereby there were seven days between each change of deprivation level. Consequently, Experiment II employed a prefeeding procedure in order to allow manipulation of motivational factors from session to session.

The experimental conditions differed in two respects from those used before. Since time to complete the fixed ratio for ball delivery (T2) had been unaffected by deprivation conditions, ball delivery was on a responsive-initiated, variable-interval schedule in the present experiment, with the aim of providing a measure more sensitive to motivational variables. In addition, an intertrial interval was introduced. Observation of the subjects in Experiment I had suggested that the longer T1 times obtained from the water group were at least partly a result of reinforcement-elicited behavior. After the dipper was presented, many of these animals would spend time around the dipper or grooming, and this behavior was not seen in the food group. With introduction of an intertrial interval, T1 times were less likely to confound postreinforcement effects and starting latencies.

METHOD

Subjects

All six rats from the food group of Experiment I served as the food group in the present experiment. In the water group, one subject died after Experiment I was completed and was replaced by a subject (R23) given identical training to the other subjects, but not previously exposed to variation in the deprivation level. Thus, as in the previous experiment, six rats served in each group.

Deprivation Schedule

All subjects were given 1.5-hr access to food and water immediately following an experimental session. Sessions were conducted five days each week; at weekend, time of access to food and water was increased to 2 hr.

In general, this schedule maintained bodyweights at, or a little below, 80% of the free-feeding level established in Experiment I. The weights of two subjects, R18 and R19, began

to sink considerably below this level, and consequently they were given 2-hr access after each session and 3 hr at weekends.

Apparatus

As in Experiment I.

Procedure

Each session again contained 27 trials. A 15-sec intertrial interval, in which there was no chamber illumination, was followed by the onset of the houselights and ball-flap light. Subsequently, the first ball-flap response initiated a variable interval, at the end of which a further response switched off the ball-flap light and delivered a ball-bearing. During pretraining, the mean intertrial interval was 8 sec, and thereafter was maintained at 20 sec. Delivery of the ball into the hole was immediately followed by delivery of a food pellet for the food group and by operation of the water dipper for the water group. With arrival of reinforcement, the appropriate flap was illuminated until the flap was operated, whereupon all lights were switched off and the next intertrial interval commenced. The white masking noise was present, without interruption, throughout the session.

Following three to seven pretraining sessions with the VI 8-sec schedule, 15 sessions of baseline training were given. For the last five sessions, consumption of food and water was measured during the free access periods following the sessions. Three blocks of five test sessions followed. After each block, subjects were kept in their home cages for two days, when times of access to food and water were adjusted if necessary to compensate for any changes in weight, and then given three additional training sessions before the next block. Five test conditions were used, which were intended to provide motivational conditions ranging from most thirst, and least hunger, achieved by providing a large amount of dry food before the session, to least thirst, and most hunger, achieved by prior provision of water. In Condition A 1 hr before a test session, a subject was given 100% of the median amount of food it had consumed following the three training sessions immediately preceding that block of test sessions. In Condition B, 50% of the amount was given. In Condition C, subjects were not given any access to food or water

before a session. In Condition D, 1 hr before a session, a subject was given 25% of the median amount of water it had consumed following the three prior training sessions and in Condition E 50% of this amount of water was given. Thus, Condition A should have induced the most thirst, and Condition E the most hunger. Each block contained each of the five conditions, whose sequence was randomized. Arbitrary pairs of food and water subjects received the same sequences.

Measures of performance were as before, except that mean response rates on the ball-flap from the first response to the end of the variable interval replaced the T2 measure used in Experiment I.

RESULTS

Performance during the 15 sessions of initial training is shown on the left-hand side of Figure 3. In this figure, initial latencies are given in the top panel, response rates in the middle panel, and ball-delivery times in the bottom panel. Initial latencies declined with training to reach a stable level over the final six sessions, with a mean value of about 7 sec in both groups. A steady increase in response rates occurred throughout the training period and there was no difference between the groups on this measure. The most interesting result from this training period was the disappearance of the difference in T3 times between the groups that had been found in Experiment I. Comparison between these results and those in Figure 2, shows that this was because T3 times for the water group increased from a mean of about 8 sec in Experiment I to a mean of about 19 sec in the first three training sessions of the present experiment.

Paired comparison tests using a logarithmic transformation were applied to the increase in T3 times between the final three sessions of Experiment I and the first three training sessions of Experiment II for the five common subjects in the water group ($t = 2.85$, 2-tailed, $p < 0.05$); a similar test of the apparent decline of T3 times over the 15 sessions showed that the difference between the first three and last three sessions was not reliable in this group ($p > 0.10$). In contrast, in the food group there was no reliable change between the end of Experiment I and the beginning of Experiment II ($t = 0.02$), but the decrease from the

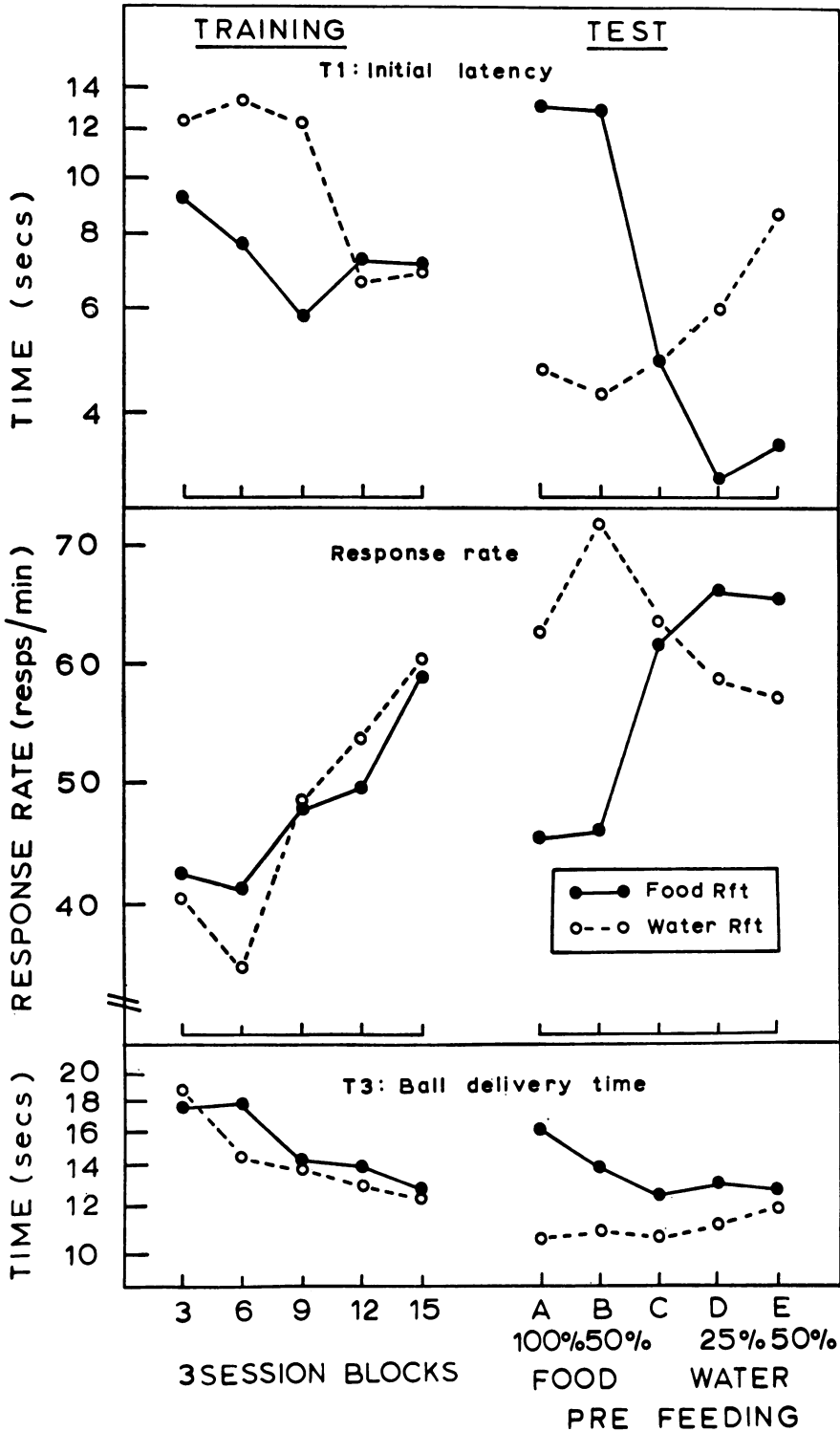


Fig. 3. Experiment II: performance as a function of number of training sessions (left-hand side) and as a function of prefeeding conditions during the test phase (right-hand side). Times are plotted on a logarithmic scale.

first to the last three training sessions in Experiment II was significant ($t = 2.23$, one-tailed, $p < 0.05$). It should be noted that, although Figure 3 indicates a general decline in T3 with continued training in both groups, the mean values at the end of the training phase were still considerably greater than the 3 to 5 sec in which, as seen from Experiment I, it was possible for a rat to take a ball and deposit it in the hole.

The results of the test sessions are summarized on the right-hand side of Figure 3. Each rat received three sessions under each of the five test conditions, and the data shown in Figure 3 are based on the median values for each of these sets of three sessions. In the food group, variations in prefeeding produced large changes in T1 and response rate. Thus, for example, in Condition A giving an animal 100% of its daily food an hour before the ses-

sion produced long initial latencies and low response rates; in Condition E, providing 50% of daily water an hour earlier produced short latencies and high response rates. Using a similar analysis to that employed in Experiment I, the differences in both initial latencies and response rates were found to be highly reliable (chi sq's > 19.3 , p 's < 0.001). In the water group, the effects were in the opposite direction, as seen in Figure 3, but were not so marked and much less reliable both for initial latencies and for response rates (chi sq's > 8.1 , p 's < 0.10).

Two measures not shown in Figure 3 are T4 and intertrial responding. No effects of test condition on T4 were detected, but intertrial responding was highly correlated with T1, such that in the food group, high intertrial response rates occurred when water had been given an hour earlier and low rates when food

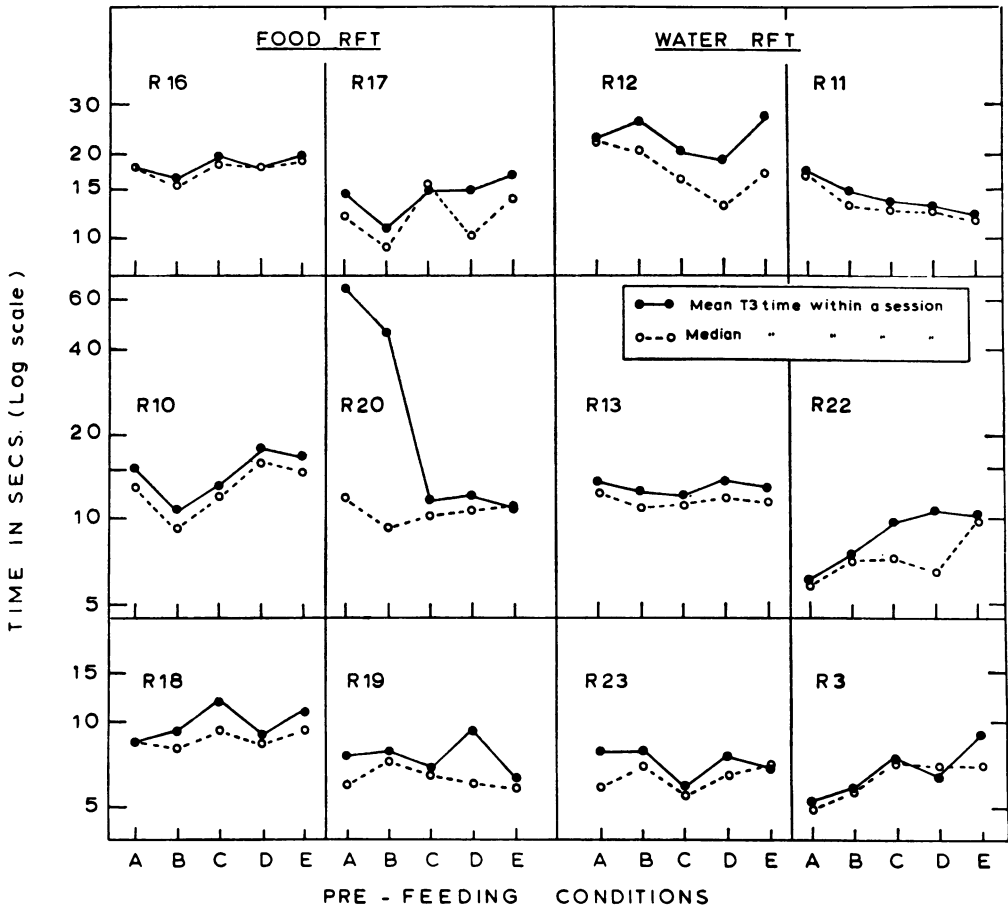


Fig. 4. Experiment II: ball-delivery times (T3) during the test phase for individual subjects. Both mean (solid lines) and median times (broken lines) within a session are shown.

had been given ($\chi^2 = 21.7$, $p < 0.001$). A tendency in the opposite direction was again observed in the water group, but was less reliable ($\chi^2 = 8.5$, $p < 0.10$).

One purpose of the test procedure was to increase the effective incentive value of reinforcement above the levels during training by prior administration of water to food-reinforced subjects and food to water-reinforced subjects. This was successful in the food group, in that initial latencies were shorter ($t = 4.25$, one-tailed, $p < 0.005$), response rates were higher ($t = 2.16$, $p < 0.05$), and there was more intertrial responding ($t = 3.50$, $p < 0.01$) in Condition D than in Condition C. Similar comparisons on these measures were also made for the water group between Conditions B and C, but only the difference in response rates approached reliability at the 0.05 level.

Despite the marked effect of the test conditions on the food group, in terms of the measures already reported and the opposite, though less reliable, effects on the water group, no effect on T3 times was detected in either group ($\chi^2 = 1.5$ for the water and 1.7 for the food group). Furthermore, inspection of the data from individual subjects produced no suggestion of an affect. In Figure 4, T3 times are shown for each subject, both in terms of the mean and median per session. Subjects are ordered in this figure so that those with long T3 times are above. The median removes distortion caused by abnormally long times on occasional trials as, for example, in the case of R20. Nevertheless, even when only the median functions for subjects displaying long T3 times are considered, these are seen to be very stable over the range of test conditions.

EXPERIMENT III: CHANGING THE TYPE OF TOKEN

This experiment was undertaken to find out whether misbehavior, as measured by T3 times, was affected by the type of token employed. Nylon ball-bearings were substituted for the steel ones. Given the difference in thermal properties between steel and nylon, one possible outcome considered before the experiment was that the reduced conductance of nylon balls would remove any similarity in cooling properties between token and reinforcement for the water group, and thus produce shorter T3 times in this group.

METHOD

Subjects

Six subjects from Experiment II served. Three were arbitrarily chosen from the food group and three from the water group. They were maintained on the same deprivation schedule as before; that is, all subjects were deprived of both food and water. Because of continued loss of weight, access time for R18 was increased from 2 to 3 hr.

Apparatus

As in Experiment I.

Procedure

Experimental conditions were exactly as in Experiment II. Immediately after the end of that experiment, subjects were given a further five sessions with the steel balls, followed by five sessions in which nylon ball-bearings of the same dimensions were substituted, and finally five sessions in which the steel balls were again used. Animals previously given food reinforcers continued with this reinforcer, as did water-reinforced subjects.

RESULTS

The T3 times of all subjects increased when the nylon balls were introduced. As shown in Figure 5, the increase in mean times was massive for several subjects. On many trials, the balls were so extensively chewed that they failed to run down the hole; on such occasions, if T3 had exceeded 3 to 5 min, the ball was taken out by the experimenter. Even when the contribution of such trials was minimized by using median T3 times, increases were still obtained, as also shown in Figure 5. There was no indication of any difference between food and water subjects. The degradation of the balls removed any previous doubts that, in mouthing the balls, water subjects were just as much attempting to chew them as were food subjects. Using a very rough criterion, an average of seven balls in each session were severely damaged by the three food subjects and an average of 10 by the three water subjects.

Other measures of performance were little affected by introduction of the nylon balls. Response rates on the ball-flap were somewhat lower during the sessions with nylon balls than during either the preceding or the following

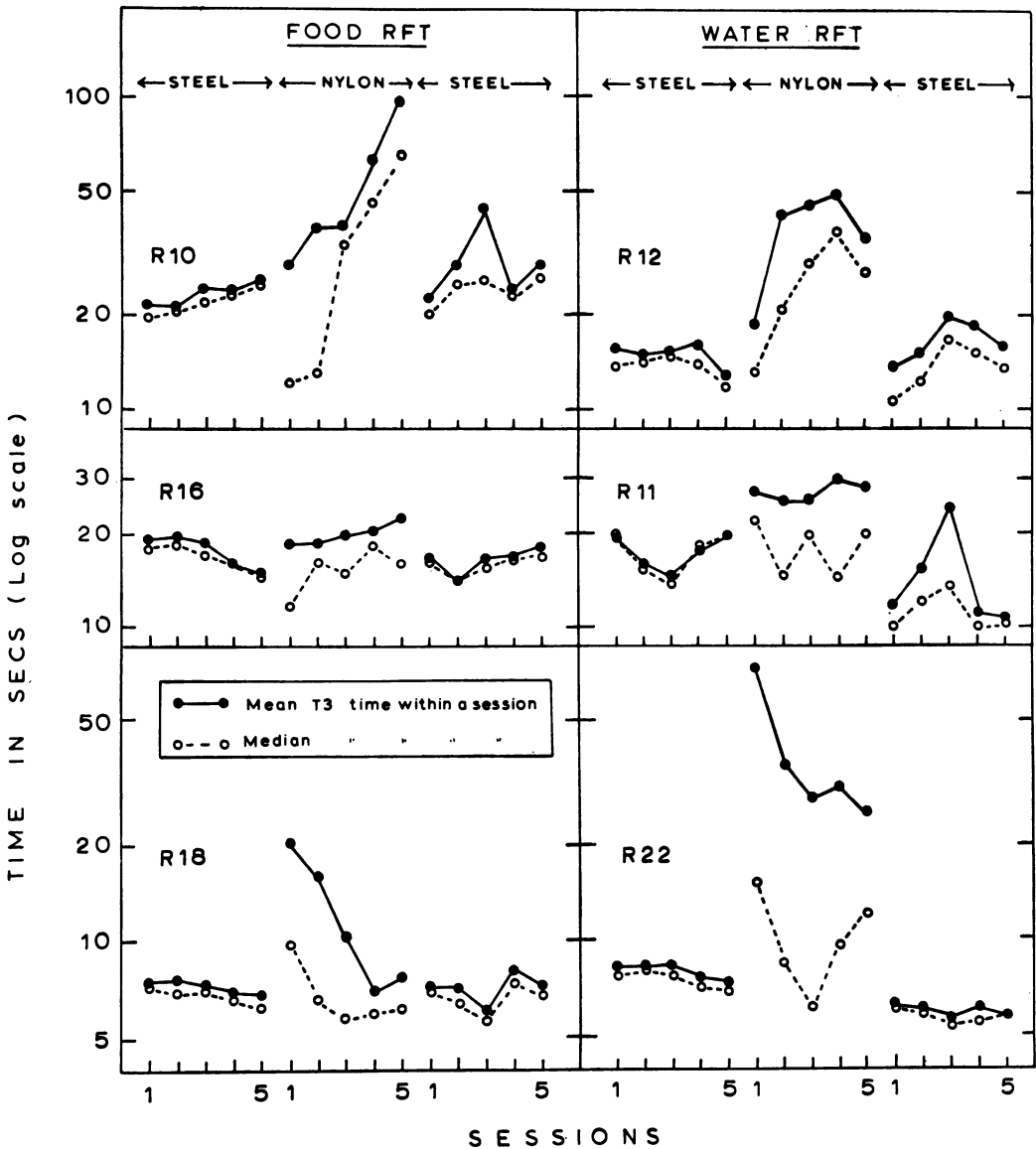


Fig. 5. Experiment III: ball-delivery times for individual subjects, showing changes after nylon balls were introduced. Both mean (solid lines) and median (broken line) T3 values are given.

sessions with steel balls, and similarly, initial latencies were somewhat longer, but these differences were not at all reliable ($p's > 0.10$).

EXPERIMENT IV: WITHIN-SUBJECT COMPARISON OF REINFORCERS

In contrast to the results from Experiment I, Experiments II and III failed to reveal any differences in T3 times between the food and water groups. In this experiment, a within-subject test for such differences was used. Hith-

erto, all subjects had been given the same kind of reinforcement from the beginning of training. In the present experiment, they were switched to the other reinforcer for the first time.

METHOD

Subjects

All 12 rats from Experiment II served, so that half had completed Experiment III and the other half only Experiment II at the beginning of this experiment. Deprivation condi-

tions were as in Experiment II, except that times of access to food and water for R19 were increased from 2 to 3 hr, as for R18.

Apparatus

As in Experiment I.

Procedure

Steel ball-bearings were used and experimental conditions were maintained as in both previous experiments. Subjects that had not served in Experiment III were given five ses-

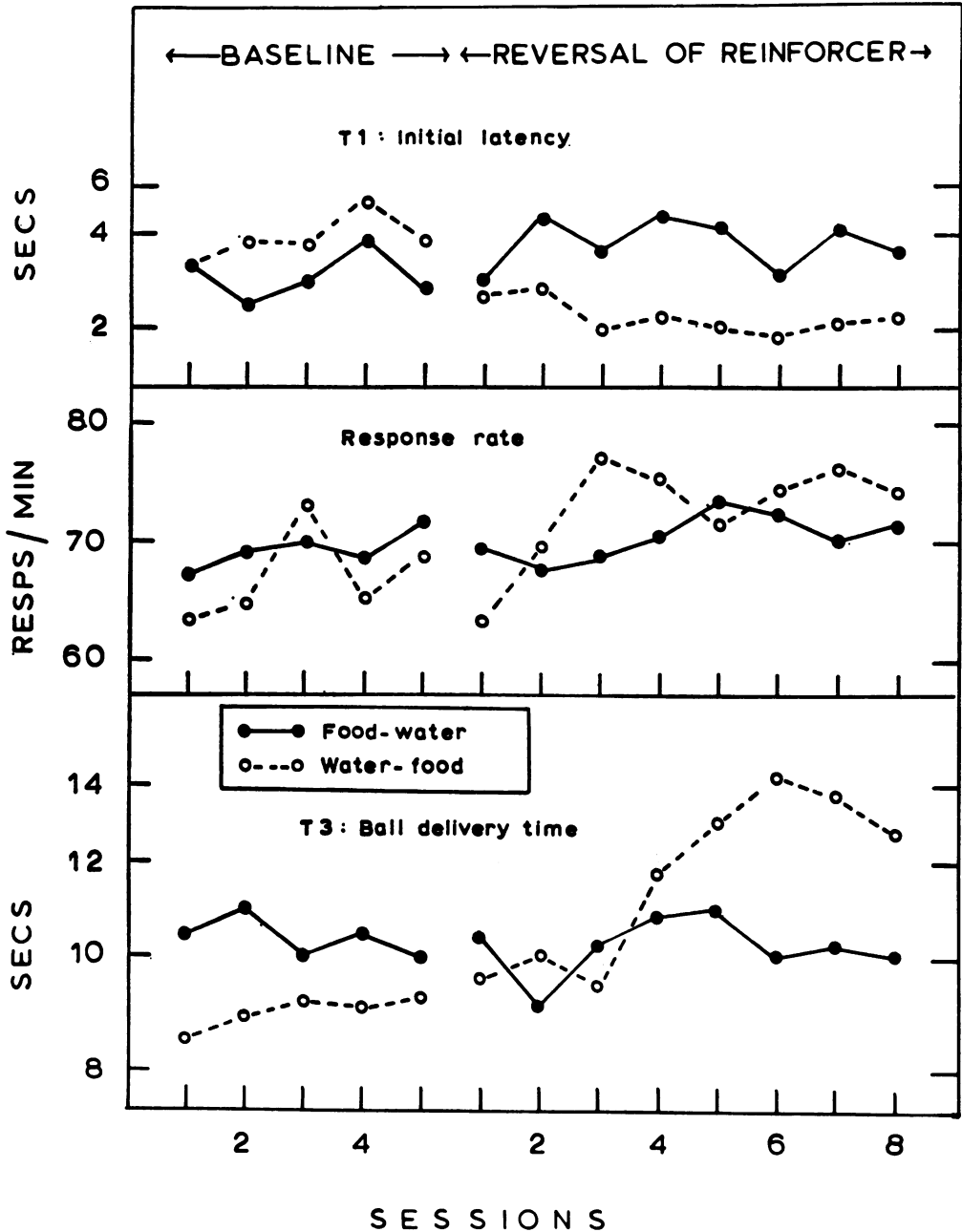


Fig. 6. Experiment IV: performance before and after reversal of reinforcer. Geometric means were used for T1 and T3 values (given for individual subjects in Table 2) and arithmetic means for response rates.

Table 2

Experiment IV: ball-delivery times (T3 in seconds) for five sessions before and eight sessions after the change of reinforcer.

<i>Food-Water Group</i>													
<i>Sessions</i>													
<i>Food Reinforcer</i>						<i>Water Reinforcer</i>							
<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>
R10	22.6	29.1	44.3	24.1	29.9	28.6	25.2	24.2	29.8	22.8	26.0	21.0	19.6
R16	16.9	14.2	16.6	17.0	18.1	18.7	17.8	21.9	18.9	20.7	17.1	17.1	17.1
R17	10.4	13.1	9.6	11.7	10.3	12.2	6.7	6.3	7.4	5.9	6.0	5.5	5.1
R18	7.1	6.9	5.9	7.9	7.1	6.1	6.7	6.3	7.4	5.9	6.0	5.5	5.1
R19	6.1	7.3	13.3	6.4	5.6	5.2	5.3	5.1	5.1	5.4	5.4	5.0	5.3
R20	10.4	8.3	9.4	7.9	8.3	9.8	6.7	9.3	9.0	9.3	8.6	8.2	9.2

<i>Water-Food Group</i>													
<i>Water Reinforcer</i>						<i>Food Reinforcer</i>							
<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>
R3	8.9	6.5	6.2	6.1	6.9	7.1	4.9	5.4	5.1	6.0	5.7	4.8	5.3
R11	11.9	15.4	24.5	11.2	10.8	17.5	14.5	14.4	19.6	19.2	20.3	18.8	17.4
R12	13.7	15.2	19.9	18.7	15.8	20.0	22.0	20.2	20.1	20.5	19.8	20.0	20.5
R13	15.6	11.7	11.9	11.9	13.1	12.6	20.1	17.9	19.3	24.8	28.6	29.8	27.1
R22	6.1	6.0	5.5	6.0	5.6	5.2	5.9	5.7	5.8	6.9	7.1	6.9	7.4
R23	7.2	10.9	9.7	13.5	15.5	12.8	11.9	10.6	16.2	21.3	22.1	24.7	23.5

sions of further training immediately after completing Experiment II, receiving the same reinforcer as they had always previously received, followed by eight sessions in which the other reinforcer was used. That is, food subjects were switched to water (food-water group) and water subjects switched to food (water-food group). For the subjects that had served in Experiment III, the present experiment began immediately after the previous one had ended. The reversal of reinforcer was introduced from the outset and maintained for eight sessions. Performance with the new reinforcer was compared to that in the final five sessions of Experiment III.

RESULTS AND DISCUSSION

The performance of the group switched from food to water was virtually unaffected by the change of reinforcer, as shown in Figure 6. Paired comparisons, using logarithmic transformations of T1 and T3 times, between the median level over the final three baseline sessions and the median over the final three sessions of the reversal phase, revealed no change in either T1, response rate, T3, or intertrial responding (all t 's < 1.43 , p 's > 0.10). In the other group, the change from water to food did affect performance; similar comparisons revealed a reliable decrease in T1 ($t = 6.2$, 1-tailed, $p < 0.01$), no change in

response rates ($p > 0.10$), and increases in T3 times and in intertrial responding (t 's > 2.29 , one-tailed, p 's < 0.05). The T3 times for individual subjects are listed in Table 2 for all 13 sessions of this experiment.

By the end of the present experiment, subjects had received a considerable amount of exposure to the basic experimental conditions. This may have been responsible for the finding that the effect of changing reinforcers was relatively small. In a final experiment, a new set of subjects was employed and the effect of changing the type of reinforcer was again assessed, but in this case after subjects had received a relatively brief amount of training. Prefeeding tests were also included. This allowed a check on the possibility that extended training could have been important in Experiment II, where changes in deprivation state produced no detectable effects on ball-delivery times.

EXPERIMENT V: FURTHER TESTS OF THE DIFFERENCES BETWEEN FOOD AND WATER AND OF A PREFEEDING PROCEDURE

This experiment employed naive subjects that were maintained under constant conditions of food and water deprivation. All were initially trained using food reinforcers. Follow-

ing this initial training and a prefeeding test, half of the subjects (the water group) were switched to water reinforcers and then returned to food. For the other half (the food group), food was used as the reinforcer throughout a comparable period.

METHOD

Subjects

Twelve naive, female hooded rats, 150 to 180 days at the start of the experiment, were housed in individual cages. Access to food and water was limited to 1 hr per day, immediately following an experimental session. This resulted in body weights that remained at approximately 80% of the prior levels.

Apparatus

The chamber was similar to the one previously used, and of the same overall dimensions. A major change was the use of a lever as the manipulandum for delivery of the steel ball-bearings. This lever was mounted between the ball and food flaps 4.3 cm above the floor, with a distance of 6.8 cm between the adjacent edges of the lever and the ball flap. A translucent Plexiglas disc, 1.8 cm diameter, which could be transilluminated by a 1-W bulb, was mounted centrally above the lever at a height of 7.8 cm above the floor. The chamber also contained a second lever, but this remained inoperative during the experiment. The only other difference between this chamber and the one in the previous experiments was the use of a striplight, 60-W 240-W ac, mounted above the translucent ceiling, which provided general illumination in place of the houselights shown in Figure 1.

Procedure

Initial shaping employed food as the reinforcer for all subjects and took a similar form to that used in Experiment I. The major difference was that, once a rat was transporting balls from the ball recess to the hole, delivery of a ball was made contingent on lever pressing. The final stage of initial training consisted of sessions containing 27 trials separated by intertrial intervals of 20 sec. At the onset of a trial, the chamber light and the light above the lever were illuminated. The first lever press initiated a variable interval with a mean length of 20 sec. At the end of this interval, the first lever press delivered a

ball and extinguished the lever light. Dropping the ball in the hole was immediately followed by delivery of a food pellet, and the subsequent operation of the food flap extinguished the chamber light and started the intertrial interval. These conditions were subsequently maintained throughout the experiment.

Once a rat had completed two such sessions, it was kept in its home cage until initial training was complete for all subjects. A further six sessions were then given, followed by 12 prefeeding sessions. These employed a procedure similar to that of Experiment II, in that 1 hr before a session commenced a subject was given either 0%, 50%, or 100% of the median amount of food it had consumed on each of the preceding five days. Each of the four blocks of three sessions included the three prefeeding conditions arranged in different randomized sequences.

On completion of the prefeeding tests, subjects were divided into two equal groups, matched in terms of two measures of performance. One was the rate of lever pressing in the 0% condition. The other was the slope of the function relating response rate to amount of prefeeding. During the 10 sessions that followed, water was used as the reinforcer for the water group, while for the food group conditions remained as before. Both groups were then given food reinforcers for five further sessions, and finally a second set of 12 prefeeding sessions, identical to the first set, concluded the experiment.

RESULTS

The initial training procedure was successful with all 12 rats and on average it took 12 sessions, with a range of seven to 18, to reach the terminal set of conditions. Behavior during initial training was similar to that described in Experiment I, but no systematic observation was carried out here. In general, ball delivery times (T_3) tended to be shorter than those of the food group in Experiment I. The fastest T_3 times were recorded from rats that pushed the ball to the hole with their noses, a pattern not seen in Experiment I.

The results of the prefeeding tests and of changing the reinforcer completely replicated earlier results. Increasing the amount of food given to a subject before a session produced increases in the initial latency (T_1) and de-

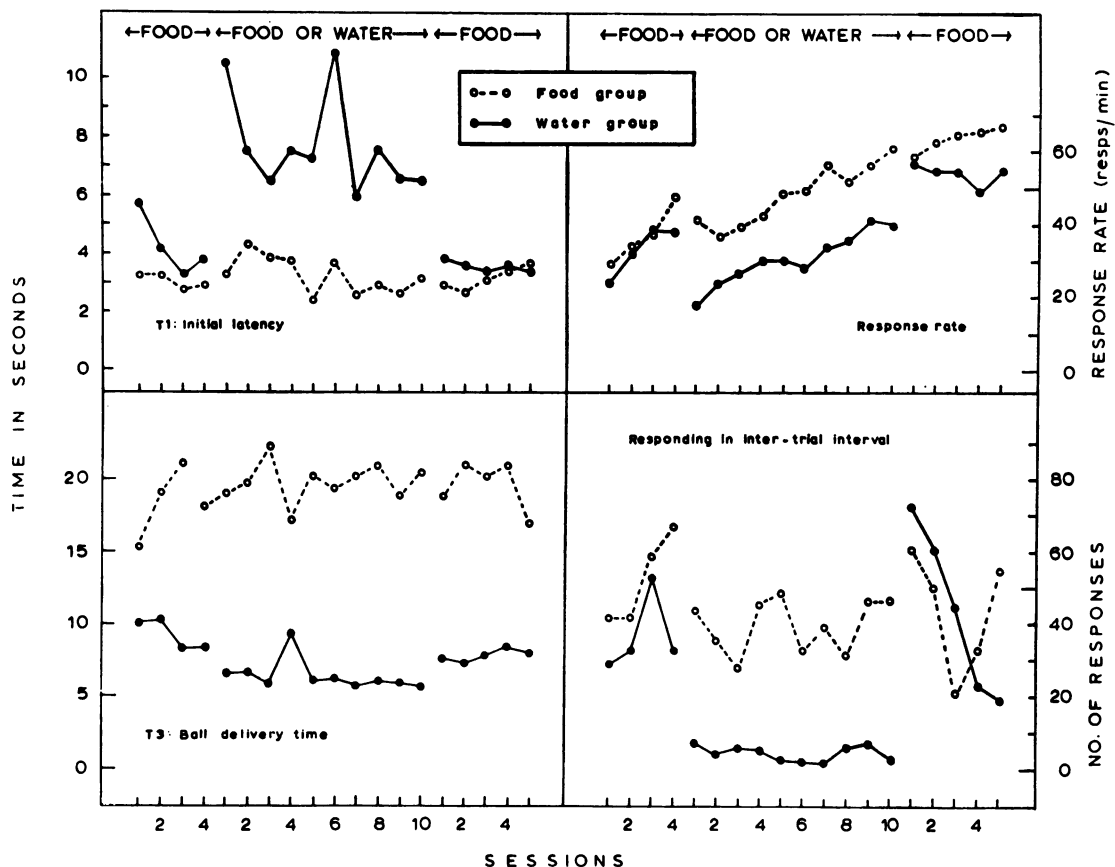


Fig. 7. Experiment V: performance during the four 0% session of the prefeeding test, during the 10-session period in which water reinforcement was used for the water group, and during the five sessions immediately following in which food was used for both groups. The group averages shown in this figure are geometric means, for T1 and T3 and arithmetic means for response rate and number of intertrial responses.

creases in the rates of lever pressing for the ball and during the intertrial interval (Friedman, chi sq's > 14.0 , p 's < 0.001). This manipulation again failed to produce any change in ball-delivery times ($p > 0.10$). The same results were obtained when these tests were repeated in the final phase, where no difference between the two groups was detected that could be attributed to their experience of different reinforcers.

Performance during the four prefeeding sessions, in which in fact no food was given before the session (0% condition), is shown in the first part of the graphs displayed in Figure 7. This figure also shows the changes that occurred with the subsequent introduction of water reinforcement for the water group, and with the final return to food reinforcement in this group. Performance during the second set of prefeeding sessions is not shown in the fig-

ure. The introduction of water increased initial latencies and reduced the rates of lever pressing for the ball and during the intertrial interval. These effects were reversed when food reinforcers were reintroduced. Using the same statistical analysis as in Experiment IV, based on the difference between the median performance of a subject in the three sessions without prefeeding before the transition and performance in the three sessions that immediately followed, all these effects were significant (t 's > 1.88 , p 's < 0.05 , one-tailed). Ball-delivery times (T3) decreased in five of the six subjects when water was introduced, but overall this change was not reliable. However, the reintroduction of food did produce a significant increase in T3 times ($t = 2.37$, $p < 0.025$). Individual results for the water group are given in Table 3. In contrast, the performance of the food group remained unchanged during

Table 3

Experiment V: ball-delivery time (T3 in seconds) of individual subjects in the Water group for (a) the sessions with zero prefeeding in the first prefeeding test, (b) three sessions that immediately followed the first prefeeding test, (c) three sessions immediately before food reinforcers were reintroduced, and (d) three sessions immediately following. Type of reinforcer present in these different phases is indicated below. The values are for mean times in a session; the two sessions marked with an asterisk (*) are ones in which the ball stuck on one trial and which therefore gave misleadingly high values.

Subject	Water Group												
	Food				Water						Food		
	1	2	3	4	1	2	3	8	9	10	1	2	3
G1	16.3	20.0	8.8	13.0	7.7	6.5	3.5	7.4	6.8	6.5	11.4	11.0	11.0
G4	4.4	5.4	6.4	6.0	5.7	4.7	5.6	5.2	5.8	5.9	6.1	7.4	8.4
G6	16.5	15.3	14.1	9.4	10.2	11.2	9.3	8.6	7.2	8.0	9.7	38.6*	7.8
G9	12.8	11.3	11.7	12.7	7.9	7.9	7.1	6.8	6.5	5.7	8.7	20.1*	10.8
G10	4.5	4.5	4.0	4.1	4.7	6.7	6.9	4.8	5.6	4.3	5.0	7.0	4.3
G12	5.2	4.5	4.9	5.1	3.3	3.1	3.0	3.5	3.3	2.7	4.1	3.4	4.0

this period, as is also seen in Figure 7, except for a steady increase in the rate of lever pressing. The method used to match subjects in the two groups unfortunately permitted a large difference in their average T3 times before the change of reinforcer in the water group. Consequently, no between-group comparisons could be made in terms of this measure.

In both this and the previous experiment, the transition from water to food produced reliable increases in T3 times, whereas in both experiments the opposite transition from food to water produced less-reliable decreases in this measure. Inspection of individual data suggested that the effect of a change of reinforcer was likely to depend on performance before the change. This is illustrated in Figure

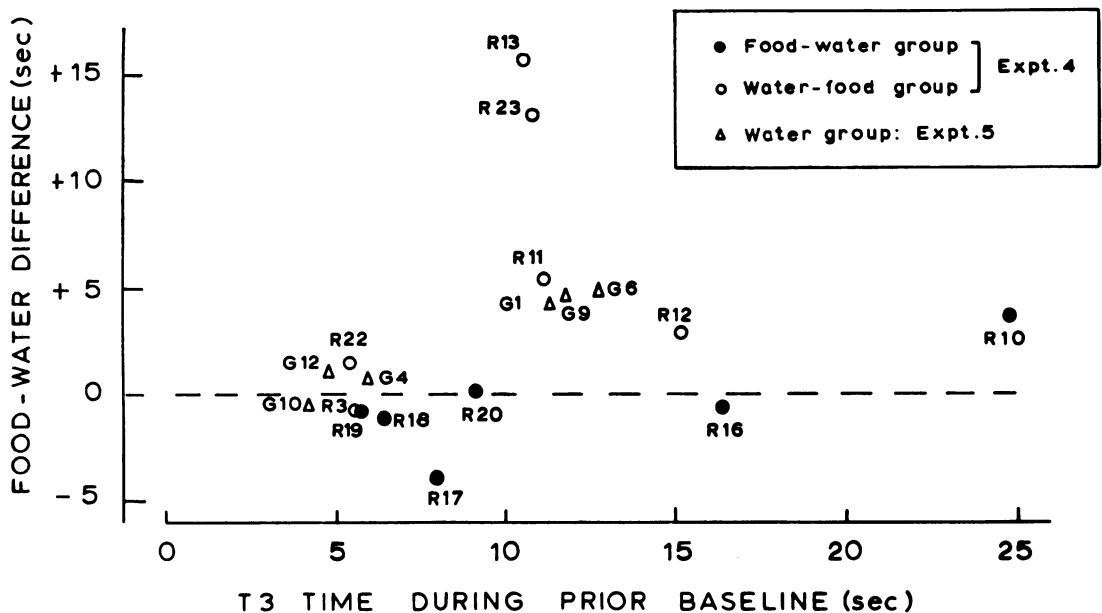


Fig. 8. Experiments IV and V: difference between delivery times with food and with water reinforcers for individual subjects as a function of the prior baseline level. The "food-water difference" for subjects in Experiment IV was based on a comparison between median T3 times in the final three baseline sessions and median T3 times in the final three sessions of the experiment. For subjects in the water group of Experiment V (G1, G3, etc.), the measure was calculated in an equivalent manner.

8, which shows T3 times from all subjects in Experiment IV and from those in the water group in Experiment V. For each of these subjects, T3 times with water were subtracted from T3 times with food and the difference is shown in Figure 8 ("Food-water Difference") as a function of the median T3 time in the three sessions preceding the change of reinforcer. There appeared to be a discontinuity at about 10 sec. Subjects with prior times shorter than this were virtually unaffected by a change of reinforcer, whereas all but one of the subjects with prior times greater than 10 sec were slower to deliver the ball when this was reinforced with food than when reinforced with water.

GENERAL DISCUSSION

The major results from this series of experiments may be summarized as follows. Many rats in the situation showed patterns of behavior that resembled those labelled as "misbehavior" by Breland and Breland. These patterns were indicated by slow ball-delivery times, which were largely occupied by attempts to gnaw the ball and which persisted despite very extensive training. Such behavior was more common in rats rewarded with food than in those rewarded with water, but the difference was not a categorical one. Average delivery times were longer with food than with water when different deprivation conditions were used (Experiment I) and when, using within-subject comparisons and constant deprivation of both food and water, both subjects trained extensively (Experiment IV) and subjects with little prior training (Experiment V) were used. Changing the reinforcer affected delivery times only in subjects that were already displaying slow delivery times.

There were two reasons for rejecting the possibility that delivery times were slower with food because food was a less-effective instrumental reinforcer. First, under constant-deprivation conditions, other measures of performance indicated that food was a somewhat more effective reinforcer than water (Experiments IV and V). Second, manipulation of deprivation conditions produced large changes in an appropriate direction in these other measures of performance, but left delivery times unaffected. Thus, for example, providing a rat with its total daily intakes of food 1 hr before the session, produced long initial latencies and

slow rates of responding for the ball, while delivery times were no longer than when the rat had been deprived of food for 23 hr (Experiment II and V).

Manipulation of deprivation conditions was undertaken primarily to examine the claim by the Brelands that misbehavior is increased by making deprivation more severe. The repeated failures to detect any change in delivery times (Experiments I, II, and V) cast serious doubt on this claim. Finally, in contrast to the lack of any effect of deprivation conditions, and to the small effect of varying the reinforcer, the change in the kind of ball used in Experiment III produced marked changes in delivery times.

These various findings lend support to the general idea that misbehavior arises when there is conflict between behavior maintained by a response-reinforcer contingency, which in the present case is of the form "relinquish the ball", and behavior maintained by a stimulus-reinforcer contingency, which is here of the general form "retain the ball". One interpretation of the constancy of ball-delivery times over a wide range of deprivation conditions is that the two kinds of behavior are equally affected by motivational variables. The experiments could not provide direct evidence that the emergence of competing behavior depended on the temporal pairings of the balls with primary reinforcement. However, various observations support this assumption. With both sets of subjects in the present study, as with the animals described by the Brelands and in the token experiments cited below, approach toward and contact with the balls was infrequent until subjects had been rewarded for such behavior. When ball-bearings were placed in the home cages of naive rats, they were ignored.

The finding that misbehavior was more pronounced with food than with water also supports the above assumption. Furthermore, this finding is compatible with the more specific account of misbehavior proposed by Moore and Jenkins (Jenkins and Moore, 1973; Moore, 1971). This account suggests that, for example, the pairing of a token with food should, according to a stimulus-substitution principle, imbue the token with food-like properties, such that it will come to elicit consummatory activity appropriate to food. However, if the nature of the primary reinforcer

were the sole determinant of misbehavior, one might expect more marked differences between food and water than those observed in the present study. Furthermore, the large effect of introducing nylon balls is difficult to account for within a simple stimulus-substitution approach. This last finding is consistent with a number of reports, based on a variety of situations, which suggest that the nature of the stimulus can be at least as important as the nature of the reinforcer in determining the behavioral consequences of a stimulus-reinforcer contingency (Boakes, 1977; Holland, 1977; Timberlake and Grant, 1975; Wasserman, 1973).

In successfully reproducing in an experimental situation the phenomena more informally observed by the Brelands, this study raises the question of why similar reports have not come from previous experimental studies of token reinforcement. A number of such studies were carried out in the late 1930s. The best known are those of Wolfe (1936) and Cowles (1937), where chimpanzees earned poker chips that could be exchanged for grapes, in the case of Wolfe's experiments, or for a variety of primary reinforcers, as in Cowles' experiments. The range of species involved in this research was extended to dogs by Ellson (1937) and to cats by Smith (1939). In almost all these experiments, the tokens were immediately exchangeable for the primary reinforcer. When work of this kind was resumed some 20 yr later by Kelleher (1957), his concern was with the effectiveness of tokens when they were not immediately exchangeable. In this, and his subsequent work on the topic (Kelleher, 1966), chimpanzees served as subjects. More recently, Malagodi (1967) reported what appears to be the first use of rats in a token experiment. In all of these studies, the main aim was to compare the effectiveness of token reinforcement with that of primary reinforcement, using mainly various kinds of discrimination situations in the earlier experiments and various schedules of reinforcement in the experiments by Kelleher and Malagodi.

What is noticeably lacking in the accounts of any of these studies is any mention of behavior resembling that observed by the Brelands and in the present study. Moore (1971) pointed out that Wolfe (1936), Cowles (1937), and Kelleher (1957) reported some mouthing

of the chips by their chimpanzees. However, there is no suggestion in these papers that this interfered with depositing tokens, and in some cases of delayed exchange it seems as though the mouth simply served as a convenient place to store tokens. Most of the papers contain considerable detail on the subjects' behavior. For example, both Ellson (1937) and Smith (1939) commented on the surprisingly small amount of transfer that occurred during training when, once a subject had learned to transfer to the receptacle a token a small distance away, the token was then placed slightly further away. Being unfamiliar with these reports at the time, we were similarly surprised by the same finding. Because of the presence of such detail, it seems likely that any form of misbehavior would have received some mention in these papers.

As reported in Experiment III, many of the present subjects severely damaged nylon balls when these were introduced. It is particularly surprising in retrospect that the tokens exchangeable for food by Ellson's dogs and by Smith's cats were small rubber balls. There is no indication in their papers that the balls sustained any damage.

It appears therefore that the use of a small object as a token that is exchangeable for food does not guarantee the appearance of misbehavior. One of the food-rewarded animals in the first set of subjects, R18, consistently failed to show much misbehavior, and in Experiment V, the T3 times of three subjects, as shown in Figure 8, were quite short. At present, the factors that determine whether an animal is prompt or slow to relinquish a token remain obscure, though it seems likely that aspects of the initial shaping procedure may be crucial. As a final note on this problem, it might be pointed out that, though the Brelands (1966, pp. 68-69) noted that a dolphin may swallow a ball when this is used as a token, what appears to be a standard routine in any dolphin show is for the animals to retrieve and promptly deliver balls and small rings, which are immediately exchanged for fish.

To conclude, the principal result of this series of experiments was the demonstration that misbehavior can be subjected to an experimental analysis. The results of individual experiments extend previously limited knowledge of the phenomenon. They favor an ex-

planation in terms of competing behavior, which is maintained by the token-primary reward contingency and whose form is largely determined by the nature of the token. At the same time, they prompt a number of questions—most importantly, what determines whether or not misbehavior occurs in a token situation—and suggest further investigation on the extent of effects due to the type of primary reward and of token employed, and on the importance of the temporal association of token and primary reward.

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